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JOURNAL FULL TITLE: Journal of Biomedical Research & Environmental Sciences
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- **DOI:** Registered with CrossRef (**10.37871**) for long-term discoverability
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JOURNAL OF BIOMEDICAL RESEARCH & ENVIRONMENTAL SCIENCES
ISSN: 2766-2276
SUBJECT AREA(S): RESPIRATORY MEDICINE | PULMONOLOGY
DOI: 10.37871

RESEARCH ARTICLE

Optimizing Respiratory Disease Management: A Systematic Review Comparing Vibrating Mesh Nebulizers and Traditional Nebulizers Devices

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Abstract

Background : Efficient bronchodilator delivery plays a crucial role in managing both acute and chronic respiratory conditions, particularly in high-stakes environments like emergency departments and intensive care units, where timely intervention is essential. vibrating mesh nebulizers (VMNs) are able to function on the basis of a vibrating mesh with microscopic holes that generate aerosolized particles, therefore offering much more consistent and efficient medication compared to Jet Nebulizers (JNs).

Objectives: This systematic review aimed to evaluate the efficacy of VMNs compared to jet nebulizers for management chronic respiratory diseases.

Methods: Four electronic databases, PubMed, Cochrane, Web Science, and Google Scholar were thoroughly searched to conduct a comprehensive literature review from 1st january 2017 till 31st december 2023. The International Prospective Register of Systematic Reviews (CRD42024507795) contains a record of the registered protocol.

Results : We identified 411 studies during the initial search; 9 studies (2.2 %) met the inclusion criteria and were included in the systematic review. The review demonstrates that VMNs offer significant advantages over jet nebulizers across various clinical settings.

Conclusion: VMNs provide better lung deposition, more efficient drug delivery, and superior clinical outcomes, particularly in the management of asthma and COPD. Additionally, VMNs are associated with fewer adverse effects and greater patient comfort, which may contribute to improved compliance and treatment success.

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DOI: 10.37871/jbres2179

Submitted: 14 August 2025

Accepted: 10 September 2025

Published: 16 September 2025

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Introducation

bronchodilator administration has become very critical in the acute and chronic respiratory diseases management , more so for emergency departments and ICUs where prompt and effective treatment matters [1]. In this aspect, the choice of the nebulizer will play a very key role in the effectiveness of bronchodilator delivery. Jet nebulizers have long been regarded as the standard in clinical practice, but advancements in nebulizer technology have introduced vibrating mesh nebulizers as a

VOLUME: 6 ISSUE: 9 - SEPTEMBER, 2025

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How to cite this article: Salameh L, AbuEbaid MH, Hamoudi R, Mahboub B. Optimizing Respiratory Disease Management: A Systematic Review Comparing Vibrating Mesh Nebulizers and Traditional Nebulizers Devices. J Biomed Res Environ Sci. 2025 Sept 16; 6(9): 1231-1241. doi: 10.37871/jbres2179, Article ID: JBRES2179, Available at: https://www.jelsciences.com/articles/jbres2179.pdf

promising alternative with improved performance [2,3]. Mechanically, these devices are at extreme ends of the spectrum concerning the mode of aerosol generation, with vibrating mesh nebulizers (VMNs)providing advantages in terms of particle size distribution, drug delivery efficiency, and patient comfort [4,5].

Utilizing a vibrating mesh with micro-scale perforations, VMNs create aerosol particles, delivering medication more consistently and efficiently than traditional Jet Nebulizers (JNs) [6]. This advanced technology enhances deposition in the lung, reduces drug wastage, and increases patient compliance [7,8]. Randomized controlled trials are being conducted on the comparative effectiveness of VMNs and JNs in most of the clinical scenarios related to COPD management, non-invasive ventilation, and high-flow nasal cannula therapy. The outcome focuses on parameters such as clinical improvement, time to symptom relief, patient comfort, treatment duration, and lung deposition efficiency [1, 9-18].

Better VMNs drug delivery translates to better clinical outcomes in the management of respiratory diseases such as asthma and COPD, where effective bronchodilator delivery may make all the difference in the course of a disease and in quality of life [19,20]. VMN use is associated with improved symptom control, reduced frequency of exacerbation, and better lung function—all parameters of central importance in the management of chronic respiratory disease [20,21].

Besides that, the use of VMNs has been associated with a reduced length of hospitalization and decreased healthcare costs. Better medication delivery through VMNs will mean quicker resolution of symptoms, hence reducing the duration of hospitalization [20]. Shorter lengths of stay, besides benefiting the patient by minimizing exposure to hospital-associated risks, also alleviate the economic burden to healthcare systems. In addition, this cost-effectiveness of VMNs is further enhanced by their durability, ease of use, and reduction in repeated treatments, which are often needed with less efficient nebulization methods [22].

This systematic review seeks to synthesize the available evidence on the comparative efficacy and efficiency of VMNs versus JNs in delivering bronchodilators. The consolidation of findings from studies within ED, ICU, and outpatient settings on the management of COPD and asthma provides a general insight into the advantages and limitations of VMNs. Ultimately, these will inform clinical practice to improve the outcomes of patients suffering from acute and chronic respiratory conditions; this also takes into account the economic implications that come with adopting these ad The later development of 'new generation' devices such as the ultrasonic nebulizer and the VMNs encouraged further study and application of aerosol therapy in critical care because of the ability of these devices to consistently generate desired aerosol particle sizes which are considered optimal for deep lung penetrationvanced nebulization technologies.

Materials and Methods

Study protocol and registration

The systematic review was conducted following the guidelines set forth by the Cochrane Collaboration and the Preferred Reporting Items for Systematic Reviews (PRISMA) statement. We registered our study in the PROSPERO database https://www.crd.york.ac.uk/PROSPERO/ (accessed on 2nd December, 2023) and were assigned the registration ID (CRD42024507795).

Search strategy and eligibility criteria

The review search strategy was begun by conducting a systematic search of the PubMed, Cochrane, Web Science , and Google Scholar databases using MeSH (Medical Subject Headings) using the terms "mesh vibrating nebulizer," "traditional nebulizer," "jet nebulizer," "ultrasonic nebulizer," "respiratory diseases," "COPD," "asthma," "lung function," and "hospital stay" (Table S1). Additionally, manual searches were performed, followed by cross-referencing relevant articles to ensure a comprehensive review of the literature. We analyzed the chosen studies using Review Manager 5.3 software, which was developed by the Cochrane Library, and we established a significance level of 5% ($p < 0.05$). The study's inclusion criteria, which investigated the effectivness of using MVNs in respiratory diseases compared with Traditional nebulizer , were limited to randomized or nonrandomized controlled human trials or experimental studies published in the English language from (1st january 2017 till 31st december 2023) and adults > 18 years old. Exclusion criteria were studies involving children (<18 years old), non-respiratory conditions, articles such as review and editorial pieces, letters to editors, brief communications, short communications, personal

opinions, and commentaries were excluded from consideration for this study.

Quality assurance and data extraction

Two independent reviewers (L.S. and M.A.) objectively reviewed the materials, and a consensus was reached by ensuring that they matched the inclusion criteria and MeSH terms. A risk-of-bias assessment was carried out using the Cochrane risk-of-bias tool for randomized trials (RoB 2) (Table S2), in accordance with the selected study criteria [23] .In addition to randomized controlled trials (RCTs), one non-randomized intervention study (Dunne et al., 2018) [24] was included to provide real-world evidence and it was evaluated using the ROBINS-I tool [25], which assesses potential biases due to confounding, selection, measurement, and reporting (S2 Table). The inclusion of non-randomized data was pre-specified to capture pragmatic outcomes and external validity . To ensure consistency in the selection of studies for inclusion, Cohen's kappa was utilized to assess inter-rater reliability between the two reviewers (approximately 20 titles and abstract screenings and 10 full-text screenings were conducted). Cohen's kappa coefficient was used to determine the level of agreement between the two reviewers, with values less than 0.20 indicating slight agreement, 0.21–0.40 indicating fair agreement, 0.41–0.60 indicating moderate agreement, 0.61–0.80 indicating substantial agreement, and 0.81–1.00 indicating perfect agreement. Any discrepancies between the reviewers were resolved through an iterative consensus process.

Data variables

The extracted data were organized based on the following criteria: first author's name and year of publication, study design, country of origin, sample size and gender, respiratory disease, Vibrating mesh nebulizer and the comparator device, Intervention and the outcome .

Results

Study selection

A comprehensive literature search was performed using PubMed (337 studies), Cochrane (37 studies), Web Science (20 studies), and Google Scholar (17 studies), which retrieved a total of 411 studies related to Vibrating Mesh Nebulizer (VMN) traditional nebulizer devices such as Jet nebulizer, asthma, and COPD. After removing duplicate studies, remained; among those studies, the titles, and abstracts of 249 were screened, resulting in the exclusion of 233 studies. The full text of the remaining articles was reviewed, and 16 were excluded based on pre-specified criteria (Figure 1). The excluded studies used animal models, children (4 articles), did not measure our outcome of interest (2 articles), or were duplicates (1 article). Of the remaining articles, nine articles were included for narrative systematic review.

Characteristics of the studies

Out of 411 studies identified during the initial search, 9 studies (2.2 %) met the inclusion criteria and were included in the systematic review. All the included studies were randomized control trails or nonrandomized interventional studies conducted between 2017 and 2023.

Three of the included studies were from Egypt [16-18], two were from the USA [26,27], one was from France [12], one was from Brazil [14], one was from Russia [11] and one was from Ireland [13]. Two studies contained both asthmatic and COPD patients [16,27], while the other seven studies; two of them used only asthmatic patients [17,26] and five only COPD patients (11-14, 18). Three studies measured lung deposition and systemic bioavailability while using VMN compared to jet nebulizers [16-18], three studies examined the impact of different nebulizer technologies on patient outcomes in both asthma and COPD, highlighting differences in efficacy, drug delivery, and overall clinical effects between VMN and jet nebulizers [11,14,26], three studies address the practicality of using VMN versus jet nebulizers in critical care unit and emergency department [11,12,27] and two studies mentioned the cost effectiveness of using VMN compared to jet nebulizers [16,27] as seen in Table 1.

Risk of bias assessment

The risk of bias assessment for each included clinical study was conducted using the Cochrane RoB 2 tool and presented in a traffic light plot (Figure S1) [28]. The traffic light plot reports five risk of bias domains: D1, bias arising from the randomization process; D2, bias due to deviations from intended intervention; D3, bias due to missing outcome data; D4, bias in the measurement of the outcome; and D5, bias in the selection of the reported result; the yellow circle indicates some concerns on the risk of bias and the green circle represents a low risk of bias. The risk of

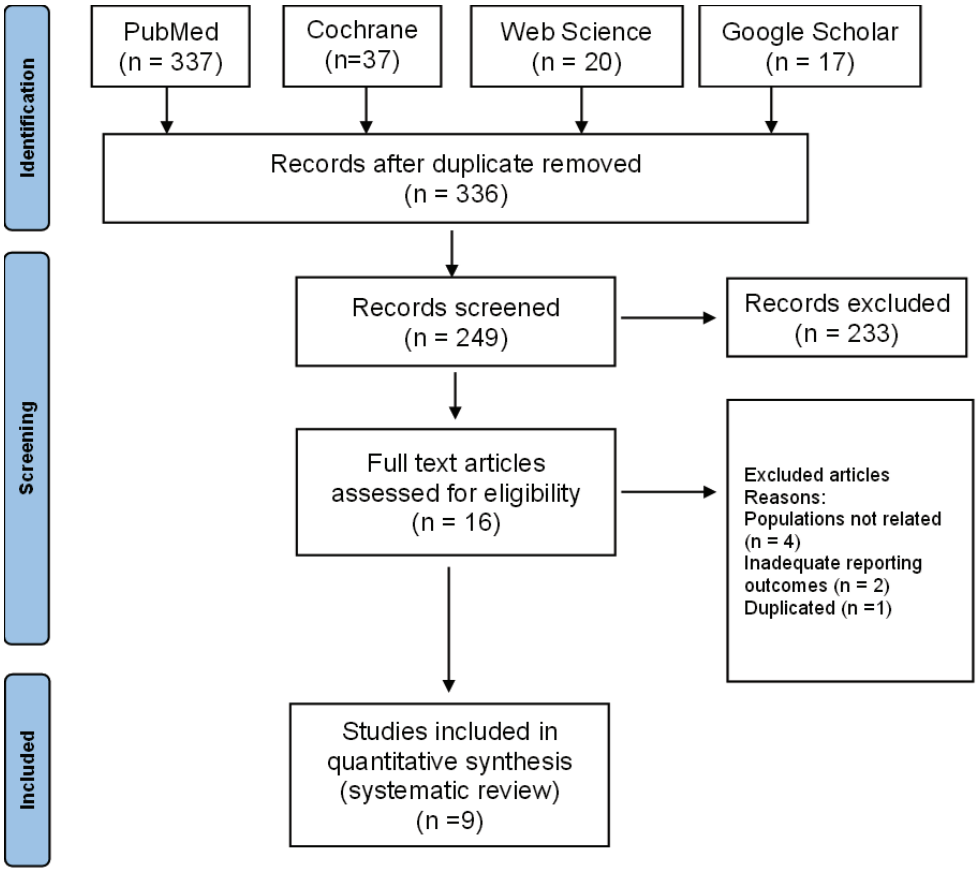

Figure 1 PRISMA flowchart depicting the study selection process according to inclusion and exclusion criteria.

bias assessment showed that all the studies included in this review were at low risk of bias, indicating that the quality of the evidence is high.

Efficacy of vibrating mesh nebulizers vs. Jet Nebulizers

Lung Deposition and Systemic Bioavailability: Of the nine reviewed studies, three studies suggested that vibrating mesh nebulizers (VMN) may offer superior lung deposition and systemic bioavailability compared to jet nebulizers, particularly in mechanically ventilated patients. Moustafa, et al. [16] compares lung deposition and systemic bioavailability of aerosolized medications delivered via different aerosol devices in mechanically ventilated patients, with and without humidification. Specifically, they found that humidification significantly reduces lung deposition across all devices [16]. The study suggests that dry conditions may be more favorable for optimal lung deposition, though they could pose a risk of drying airways. Overall, it highlights the importance of balancing humidity levels to optimize drug delivery and patient safety [16]. In the other study for Moustafa, et al. [17] focused on the clinical outcomes related to different inhalation methods in asthmatic patients under mechanical ventilation, with and without humidification. It supports the previous findings that humidification reduces lung deposition and suggests that humidified aerosols may lead to suboptimal clinical outcomes in such patients [17]. However, humidification is sometimes necessary to prevent airway drying, so the choice of aerosol device and the level of humidification need to be carefully considered [17]. Moreover, Saeed, et al. [18] this study examines how fill volume and humidification affect aerosol delivery during noninvasive ventilation. It confirms that higher fill volumes and the absence of humidification enhance lung deposition [18]. The findings suggest that careful adjustment of these variables is crucial to maximizing the efficiency of drug delivery, especially in noninvasive ventilation settings [18]. Overall, these studies suggest VMN tend to maintain more consistent aerosol particle size and distribution, which can be compromised by the humidification required in ventilated patients. Jet nebulizers, in contrast, are more affected by humidification, leading to reduced drug delivery

efficiency. This difference highlights the potential advantage of using VMN over jet nebulizers in clinical settings where optimal drug deposition is critical.

Inhalation Methods and Clinical Outcomes in Asthma and COPD: Three studies examined the impact of different nebulizer technologies on patient outcomes in both asthma and COPD, highlighting differences in efficacy, drug delivery, and overall clinical effects between VMN and jet nebulizers as seen in study Chweich, et al, 2023. (26) Avdeev, et al. [11] Galindo-Filho, et al. [14]. The study by Chweich, et al. [26] there primary goal was to determine whether the use of a VMN would lead to better clinical outcomes compared to a standard jet nebulizer in the treatment of severe asthma exacerbations. The study reported a percentage increase in FEV1 that was significantly higher in the group using the VMN (average **25%** increase) compared to the jet nebulizer group (**18%** increase) and they noted that noted that patients receiving treatment through the VMN experienced a shorter time to clinical improvement, indicating that this device may be more effective in managing acute asthma exacerbations rapidly, which leading to faster and more significant improvements in lung function without increasing side effects.

Avdeev, et al. [11] conducted a randomized controlled trial to compare the clinical outcomes of using a VMN versus a jet nebulizer during noninvasive ventilation in patients experiencing acute exacerbations Of Chronic Obstructive Pulmonary Disease (COPD). They measured the improvement in lung function, specifically FEV1 and the time to clinical stability, hospital length of stay, and the rate of treatment failure (defined as the need for intubation). They found that the patients treated with the VMN showed a greater improvement in FEV1(14% improvement) compared to those using the jet nebulizer (8% improvement), this demonstrates that the vibrating mesh nebulizer provided a more significant enhancement in lung function during the treatment of acute COPD exacerbations [11]. Moreover, VMN group reached clinical stability faster, with a reduction in time by approximately 12-24 hours compared to the jet nebulizer group and the length of hospital stay was averaging about 2 days less [11]. As well as they reported that the rate of treatment failure was **20%** in the VMN group, compared to **35%** in the jet nebulizer group. This indicates a significant reduction in treatment failure with the use of the VMN during noninvasive ventilation in acute exacerbation of COPD [11]. Galindo-Filho, et al. [14] provided insight into the mechanisms behind clinical outcomes by demonstrating the higher lung deposition efficiency of VMN. So, they focused on evaluating the efficiency of bronchodilator delivery using VMN compared to jet nebulizers during noninvasive ventilation in COPD patients, with a specific emphasis on aerosol lung deposition measured by radiolabeled aerosols. They found specifically, the VMN delivered approximately **30%** of the aerosolized dose to the lungs, while the jet nebulizer delivered only about **10%**. This marked increase in lung deposition suggests that the VMN is more efficient in delivering medication, which could contribute to lower treatment failure rates, even though this specific metric was not directly measured in the study [14]. Although FEV1 was not directly measured, the study found that the VMN delivered a higher percentage of the bronchodilator to the lungs [14], suggesting potentially better clinical outcomes similar to those observed by Avdeev, et al. [11] In summary, VMN demonstrated superior efficacy and efficiency in both asthma and COPD treatments, with higher FEV1 improvements, faster clinical stability, reduced hospital stays, and better medication deposition compared to jet nebulizers.

Efficiency and Practicality in Various Clinical Settings

Device Performance in Critical Care and emergencies: Three studies address the practicality of using VMN versus jet nebulizers in different clinical settings. Dunne, et al. [28] specifically evaluates the use of nebulizers in the emergency department, making it highly relevant to understanding the practicality of different nebulizer technologies in an acute care setting. The study involved 60 patients and found that the VMN group had a 22% increase in FEV1, compared to 15% in the jet nebulizer group, and achieved symptom improvement 30 minutes faster [27]. Avdeev, et al. [11] conducted a randomized controlled trial with 80 COPD patients in critical care unit (ICU) , demonstrating that the VMN group showed a 14% improvement in FEV1, compared to 8% in the jet nebulizer group, reached clinical stability 12-24 hours faster, and had a 2-day shorter hospital stay. Bodet-Contentin, et al. [12] was conducted in the ICU setting. It evaluated the efficacy of salbutamol nebulization using Vibrating Mesh Nebulizers (VMN) compared to jet nebulizers during noninvasive ventilation in COPD patients. Finding that the VMN provided significant improvements in FEV1 and quicker clinical response, alongside a shorter hospital stay compared to the jet nebulizer group. These studies provide valuable

insights into the practicality and effectiveness of nebulizer technologies in various clinical settings, focusing on outcomes like FEV1 improvement, time to clinical response, and hospital stay duration.

Cost-effectiveness analysis of vibrating nebulizer technology: Among the nine studies reviewed, two specifically address cost-effectiveness and resource utilization related to nebulizer technologies. Dunne, et al. [24], this study directly assesses the cost-effectiveness of VMN compared to jet nebulizers within an emergency department setting. By evaluating the total costs associated with each nebulizer type—including equipment, medication, and time required for treatment—the study provides insight into how VMN can lead to cost savings [27]. Results indicated that VMN was associated with lower overall costs due to reduced medication use and shorter treatment times, which translated to more efficient resource utilization. Specifically, the average time for nebulization with VMN was reduced by approximately 10 minutes compared to the jet nebulizer, contributing to lower healthcare costs and improved efficiency in the emergency department [27]. Although Moustafa, et al. [16] study's findings on improved drug delivery efficiency with VMN could, the study indirectly suggest potential cost savings due to more effective medication use, it does not explicitly quantify or analyze these cost aspects.

Safety and Adverse Effects

Adverse effects related to device use and patient tolerability and comfort: The following studies focus on comparing the use of VMNs and standard jet nebulizers, with an emphasis on assessing adverse effects across various clinical scenarios. Dunne, et al. [24] reported that both VMNs and jet nebulizers were generally well-tolerated by patients. However, the incidence of side effects was lower in the group using VMNs compared to those using jet nebulizers. Common side effects included mild throat irritation and a sensation of dryness, which were less frequently reported in the VMN group [27]. Moreover, patients using VMNs reported a more comfortable experience, likely due to the quieter operation and smaller particle size generated by VMNs, leading to a smoother inhalation process [27]. Avdeev, et al. [11] reported incidence of adverse effects such as throat irritation and coughing were slightly lower in the group using Vibrating Mesh Nebulizers (VMNs) compared to those using jet nebulizers. But, using VMNs reported greater comfort during the treatment. This improved comfort was attributed to the quieter operation of VMNs and their more consistent and efficient drug delivery [11]. Cushen, et al. [13] observed that both types of nebulizers—VMNs and jet nebulizers—were associated with mild and generally manageable adverse effects. These effects included mild throat irritation, coughing, and a sensation of dryness in the airways. The frequency and severity of these side effects were similar between the two groups. While both nebulizers were effective in delivering bronchodilators, the VMN was associated with a slightly better tolerance among patients, possibly due to its quieter operation and more efficient drug delivery [13]. Overall, the findings suggest that while both nebulizer types are safe and effective for bronchodilator administration in patients with COPD exacerbations, VMNs may offer a slight advantage in terms of patient comfort and reduced minor side effects [13]. Chweich, et al. [26] reported that both vibrating mesh nebulizers VMNs and jet nebulizers were generally well-tolerated by patients experiencing severe asthma exacerbations. The adverse effects observed were mild and similar between the two groups, including minor throat irritation, coughing, and a transient increase in heart rate due to the bronchodilator medication. No severe adverse effects were reported, indicating that both VMNs and jet nebulizers are safe options for administering bronchodilators in patients with severe asthma exacerbations [26]. While the efficacy in bronchodilator delivery was similar, the VMN was associated with improved patient comfort due to its quieter operation and more consistent drug delivery, which may contribute to better patient compliance [26]. Across the studies, Vibrating Mesh Nebulizers (VMNs) generally showed a slight advantage over jet nebulizers in terms of side effects and patient comfort. VMNs were associated with fewer minor side effects such as throat irritation and coughing, and patients consistently reported a more comfortable experience. This improved comfort was largely attributed to the quieter operation of VMNs and their more consistent and efficient drug delivery. Although both nebulizer types were effective and safe for bronchodilator administration in various clinical scenarios, VMNs offered better patient tolerance, potentially leading to improved compliance.

Discussion

In our study, the outcomes of the included studies which focused on efficacy of VMNs compared to jet nebulizers for management chronic respiratory

diseases. The review demonstrates that VMNs offer significant advantages over jet nebulizers across various clinical settings. VMNs provide better lung deposition, more efficient drug delivery, and superior clinical outcomes, particularly in the management of asthma and COPD. The studies Moustafa, et al. [16], Moustafa, et al. [17] and Saeed, et al. [18] suggest that VMNs may offer superior lung deposition and systemic bioavailability compared to jet nebulizers, particularly in mechanically ventilated patients. Moustafa, et al. [16] emphasized that while humidification can reduce lung deposition across all aerosol devices, the effect is less pronounced in VMNs compared to jet nebulizers. This indicates that VMNs might maintain more consistent aerosol particle size and distribution, even under humidified conditions, which is crucial in achieving optimal drug delivery in ventilated patients. Saeed, et al. [18] further supported this by demonstrating that higher fill volumes and the absence of humidification enhanced lung deposition, particularly in noninvasive ventilation settings. Overall, VMNs appear to be less affected by the challenges posed by humidification, making them a potentially better option for ensuring effective drug delivery in clinical scenarios where optimal lung deposition is critical. The effect of device-related factors has been reviewed elsewhere [29,30]. Appropriate particle sizes are important to enable adequate concentrations at the target site. Particle size also determines the mechanism of deposition in the respiratory system [31]. Particles that distribute deep in the smaller airways (<5 μm) are reported to have up to 70 % deposition efficiency [32,33]. Smaller particles (1–3 μm) are considered to have the optimal droplet size for efficient deposition in the alveolar airspaces, for systemic delivery [34]. In this regard, the efficiency of the aerosol device can be defined to be the ability to generate the aerosol in the desired particle size range. VMN encouraged further study and application of aerosol therapy in critical care because of the ability of these devices to consistently generate desired aerosol particle sizes which are considered optimal for deep lung penetration [35,36]. Mesh nebulizers are the result of improvement in nebulizer technologies; they are more efficient and with significant advantages compared to other nebulizers devices [37].

In addition, other studies, such as those of Chweich, et al. [26], Avdeev, et al. [11], Galindo-Filho, et al. [14], mentioned the impact of different nebulizer technologies on clinical outcomes in asthma and COPD. Chweich, et al. [26] found that VMNs led to more significant improvements in lung function (as measured by FEV1) and quicker clinical recovery in patients with severe asthma exacerbations. Similarly, Avdeev, et al. [11] demonstrated that VMNs were more effective in improving lung function and reducing treatment failure rates in COPD patients undergoing noninvasive ventilation. These findings were corroborated by Galindo-Filho, et al. [14], who highlighted the superior lung deposition efficiency of VMNs, suggesting that the higher medication delivery efficiency likely contributes to the better clinical outcomes observed with VMNs. Airflow and tidal volume influence the effect of airway anatomy on aerosol deposition. Patients suffering from airway obstruction such as asthma or COPD have impaired mucociliary clearances and mucous retention [38]. For drugs with poor trans-mucous permeability (e.g., aerosolized aminoglycosides) this could mean reduced drug delivery and hence impaired efficacy, although this is yet to be confirmed in clinical studies [39]. Chronic inflammation may result in airway remodeling, which changes the dynamics of airflow [33,40], and impaired mucociliary clearance, thus reducing the pulmonary drug deposition [33,41]. These changes lead to a proximal shift in the airway deposition pattern of the aerosols [41]. Vibrating Mesh Nebulizers (VMNs) are designed to produce a fine, consistent aerosol with a specific particle size that can effectively penetrate the airways, even in patients with obstructive conditions like asthma or COPD [41]. The impact of airflow and tidal volume, as well as the changes in airway anatomy due to chronic inflammation, significantly influence aerosol deposition. VMNs offer significant advantages by producing fine, consistent aerosols, they help improve drug deposition even in the presence of airway obstruction, remodeling, and impaired mucociliary clearance, potentially leading to better therapeutic outcomes.

Furthermore, the practicality of using VMNs in different clinical settings was examined in studies by Dunne, et al. [24], Avdeev, et al. [11], and Bodet-Contentin, et al. [12]. These studies consistently found that VMNs outperformed jet nebulizers in terms of FEV1 improvement, time to clinical response, and duration of hospital stays, particularly in critical care and emergency settings. The faster symptom relief and improved clinical outcomes associated with VMNs highlight their practicality in high-stakes environments like emergency departments

and ICUs, where time-sensitive interventions are crucial. The retrospective study reported significantly lower total dose of albuterol, fewer admissions, more discharges, and shorter ED length-of-stay, in patients treated with VMN compared with those treated with JN. However, Cost-effectiveness is another important consideration when evaluating nebulizer technologies. Dunne, et al. [24] found that VMNs were associated with lower overall costs due to reduced medication use and shorter treatment times in an emergency department setting. Although Moustafa, et al. [16] did not directly quantify cost savings, their findings on the improved drug delivery efficiency of VMNs suggest potential cost benefits. But there is limited quality evidence on the comparative clinical effectiveness of VMN as compared to JN devices for patients with respiratory conditions in acute care settings. Further high-quality research is required to definitively demonstrate comparative clinical effectiveness of VMN and JN. We believe future randomized controlled studies are required to determine the undiluted effect of device type on sub populations of patients with primary respiratory disease such as asthma and COPD, and for prospective cost data collection.

The safety profiles of VMNs and jet nebulizers were compared across several studies, with a focus on patient comfort and adverse effects. Studies by Dunne, et al. [24], Avdeev, et al. [11], and Cushen, et al. [13] reported that both devices were generally well-tolerated, but VMNs were associated with fewer minor side effects such as throat irritation and coughing. The quieter operation and more consistent drug delivery of VMNs contributed to a more comfortable experience for patients, potentially leading to better compliance and overall treatment outcomes. Chweich, et al. [26] similarly noted that VMNs were associated with improved patient comfort during severe asthma exacerbations, which could be a key factor in their superior efficacy. Finally, although the RCTs delivered controlled proof of the clinical advantages of vibrating mesh nebulizers over jet nebulizers, Dunne, et al. [24] presented significant real-world data from a substantial emergency department cohort. Despite being non-randomized and thus more susceptible to confounding factors, the study showed consistent trends in lower admission rates and decreased albuterol dosage needs with VMN application. Incorporating this evidence enhances the external validity of our results, yet confidence in the evidence is reduced because of limitations in the study design. Consequently, our findings are mainly based on RCT data, while the non-randomized evidence acts as supplementary contextual information Clinical implications indicate that VMNs suggest that they may enhance the efficiency of drug delivery and increase patient adherence relative to JNs, especially in the management of chronic diseases

Conclusion

The review demonstrates that Vibrating Mesh Nebulizers (VMNs) offer significant advantages over jet nebulizers across various clinical settings. VMNs provide better lung deposition, more efficient drug delivery, and superior clinical outcomes, particularly in the management of asthma and COPD. Additionally, VMNs are associated with fewer adverse effects and greater patient comfort, which may contribute to improved compliance and treatment success. These findings suggest that VMNs could be the preferred choice for bronchodilator administration, particularly in settings where optimal drug delivery and patient comfort are critical.

Limitations

The generalizability of these findings might be restricted by the diversity of the study populations and healthcare settings involved. Different healthcare systems and patient demographics could influence the effectiveness and efficiency of nebulizer use, suggesting that further research is needed to explore these effects across various global contexts. Most studies focus on short-term outcomes with a lack of long-term data, and there is limited exploration of cost-effectiveness and patient adherence. Additionally, potential biases, such as small sample sizes and publication bias, may influence the findings. Practical considerations like device maintenance and environmental impact are also not thoroughly addressed.

Clinical Trial Number: Not applicable.

Declarations

Ethics approval and consent to participate: Not applicable.

Consent for Publication: Not applicable.

Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests: Not applicable.

Funding: Not applicable.

Authors' Contributions: Conceptualization, L.S., M.A. and B.M.; methodology, L.S and M.A.; software, R.H.; Studies review, L.S. and M.A.; data curation, L.S. and M.A.; writing—original draft preparation, L.S., B.M and R.H.; writing—review and editing, L.S., R.H. and M.A; visualization, B.M and R.H.; supervision, B.M.; All authors have contributed equally to this work. All authors have read and agreed to the published version of the manuscript.

Supporting information

S1 Figure: This is the S1 Fig Title. This is the S1 Fig: Traffic light plot for risk of bias assessment.

S1 Table: This is the S1 Table Title. Research strategy table

S2 Table: This is the S1 Table Title. ROBINS-I Risk of Bias Assessment table

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